STATIC ANALYSIS OF CURVED CABLE STAYED BRIDGE AS PER IRC

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ABSTRACT

The Innovative bridge design discussed here is a curved cable stayed bridge as per Indian Road Congress (IRC). This work is highlighting a close technical concept between aesthetic choices and structural performance which is to justify the initial conceptual analysis. The superstructure of the bridge consists of a multi-cell concrete box girder. The single pylon of the bridge is a hollow rectangular section. The single pylon is made of high strength of concrete to provide strength and stiffness in a pylon. A linear static structural analysis will be carried out using some commercial code, including relevant parameters calculation to check as per IRC Standards.

KEY WORDS: Cable-Stayed bridge, Curved Span, Curved deck bridge, Static Analysis, Indian Road Congress (IRC).

I. INTRODUCTION

In recent years, cable stayed bridge have become one of the most frequently used bridge systems throughout the world. A well designed bridge should satisfy certain basic criteria in well-portioned and unified structures. Almost all existing Cable Stayed bridges are straight. There are only a few known cable stayed bridge with a curved roadway. Example of curved cable stayed bridge is steel "S-shaped" bridge in Japan with to vertical towers. Second one is in Sunniberg bridge in Switzerland with small height pylon. A cable stayed bridge basically comprises three structural elements: the Cable system, girder and tower or pylon. In general, the pylon of a cable stayed bridge is its most conspicuous element.

In this paper, I have using only geometry data of "Pandit Dindayal Upadhyay" Cable Stay Bridge across river Tapi joining Athwa and Adajan.

1.1 Single Pylon for Curved Alignments:

Bridges towers can be classified on the basis of the numbers of legs, A or H Shaped towers have two legs. A single Pylon stands on one leg, corresponding to a vertical or nearly vertical line. A Single Pylon is the simplest, most straight forward pylon form.

II. STRUCTURAL MODEL CONFIGURATION

A three dimensional finite element model was ready in MIDAS CIVIL 2016 software, which is a advanced software of design in India for cable stayed bridge analysis. The following table indicates the material properties and sectional properties were used to prepare a model: (see table :1 and 2)

2.1 Geometry of Bridge:

Total span = 300 m.

Main span = 150 m.

Side span = 75 m. (2 x 75m = 150 m).

Number of pylon : 2 Nos.

Pylon type : Single type

Number of lane : 4

Number of cable plane : 1

Number of cable : 24 Nos.

Degree of Curvature : 30'

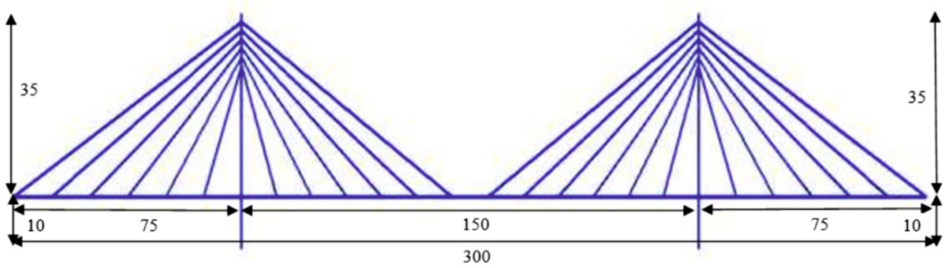
Table 1:. Material Properties

Material Name	Type	Standard	Grade	Elasticity (kN/m^2)	Poisson Ratio	Density kN/m3
Girder	Concrete	IS(RC)	M 50	3.5355e+007	0.2	2.3600e+001
Pylon	Concrete	IS(RC)	M 50	3.5355e+007	0.2	2.3600e+001
Cable	Steel	IS(S)	Fe 540	2.0500e+008	0.2	7.6980e+001

Table 2:. Sectional Properties

Section Name	Section Dimension		Area (m^2)	Iz (m^4)	Iy(m^4)
	Width(m)	Height(m)			
Girder	26	3	34.13	1.45e+003	3.79e+001
Pylon	5	4	7.00	2.05E+001	8.58
Cable	0.3		7.00e-002	3.97e-004	3.97e-004

ELEVATION



*All dimensions are in meter.

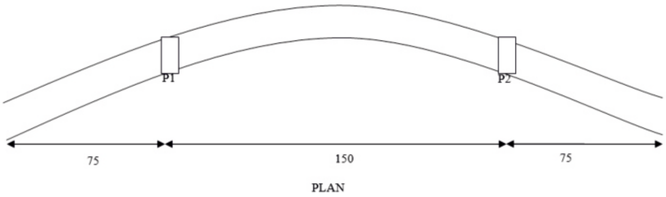


Figure 1 : Elevation and Plan layout of Curved cable stayed bridge

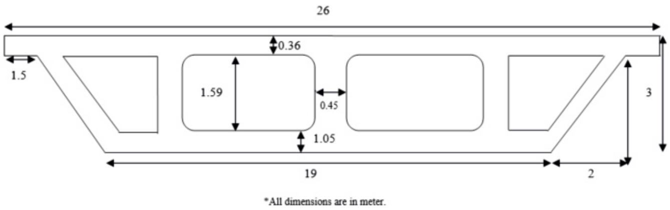


Figure 2 : Schematic Diagram of Multi-cell Concrete Box Girder

The following condition and assumptions are used in the modeling process :

1. The moving load used as per IRC 6 : 2014 Section : II LOADS AND STRESSES specifications Class A Loading and Class AA loading.
2. Girder Design as Per IRC 112:2011 CODE FOR PRACTISE FOR CONCRETE ROAD BRIDGES.
3. The Yield Stress of cable is 1860 Mpa.
4. The Girder concrete grade is M50 with design compressive stress is 16.5 Mpa.
5. The pylon concrete grade is M50.

The Multi-cell concrete box girder bridge is shown in figure-1. The girder depth is 3m and schematic diagram and detailed summary shown in figure-2. the pylon shape is Single type with cable arrangement system is fan system. The cables are high strength parallel strength with yield stress 1860 Mpa.

III. STATIC ANALYSIS

Static analysis is done by MIDAS CIVIL 2016 Software under load combination of Dead Load and Moving Load shown in the figure.

Table No 3 : Load Combination

Load	Value
Dead load	Calculate by software.
Secondary Dead Load	88.14 kN/m.
Moving Load	Class A + Class AA loading

3.1 Secondary Dead Load Calculation:

Secondary Dead Loads like Barriers, Footpath and kerb is generally taking as 0.5 kN/m^2 u.d.l. with entire Span.

Now, Asphalt Density = 2200 kN/m^2

Assume Wearing Coat = 80 mm

Secondary Dead Load = 22 x 0.08

= 1.76 kN/ m^2

Total Secondary Dead Load = 1.76 + 0.5

= 2.26 kN/m^2

Total Width of Deck = 26 m

Secondary Dead Load along deck = 26 x 2.26

= 58.76 kN/m

Total Factored Secondary Dead Load = 1.5 x 58.76

= 88.14 kN/m

Static Effects in Bridge Completion Stage

Figure-3 Shows axial force in girder. The origin of the horizontal axis is the same as the x-axis in figure –1.

3.2 Girder Axial Force :

For M-50 grade concrete, the permissible stress according to IRC:18-2000 are : Characterstic strength of concrete,

F_{ck} = 50 N /mm^2

Maximum allowable compressive stress,

F_{ci} = 0.33 x F_{ck}

IRC : 18-2000
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= 0.33 x 50

= 16.5 N / mm^2

First, Stress in N / mm^2 converted into kN/m^2

= 16500 kN / m^2

Second, Stress converted into force

$$\text{Girder Stress} = \frac{\text{Girder Force}}{\text{Area}}$$

= 16500 x 34.13

= 563145 kN

At Near Pylon,

The Girder force = 300365.6 kN

300365.6 < 563145 kN.

=O.K

It indicate that the maximum girder axial force is more at nearer to pylon 3.00E+05 kN and less at the abutment at 7.88E+03.

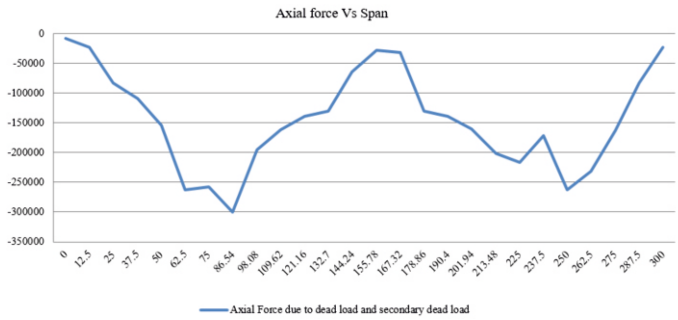

Figure 3 : Axial force of girder under effect of Dead Load

3.3 Girder Stress :

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IRC : 18-2000
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= 0.33 x 50

= 16.5 N / mm^2

It indicate that the maximum girder compressive stress at the nearer pylon 9.23 and girder compressive stress is less at the abutment 3.46E-01.

Maximum stress in girder = 9.23 N / mm^2

< 16.5 N / mm^2

= O.K

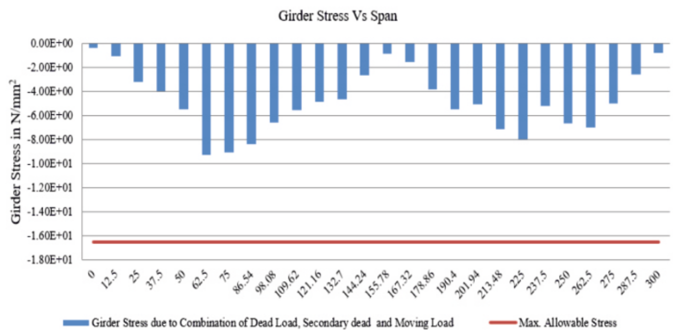

Figure 4 : Girder stress due to combination of Dead Load +Secondary Dead Load + Moving load

3.4 Cable Stress

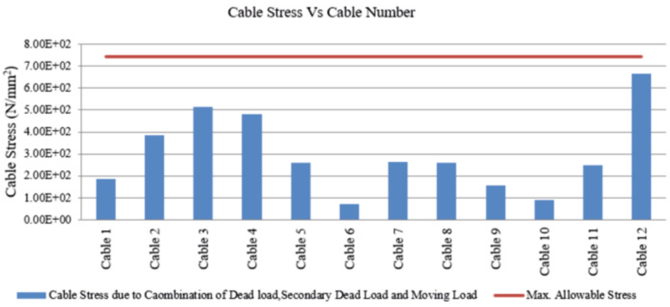

Figure 5 : Cable stress due to combination of Dead Load + Secondary Dead Load + Moving load

We are using Hight Strength parellal strand and its yield stress of cable is 1860 N/mm^2.

Under Dead Load + Secondary Dead Load + Moving Load allowable stress is

= 0.4 x Yeild stress of cable.

= 0.4 x 1860

= 744 N/mm^2.

Maximum Cable Stress is 667 N/mm^2 which is under allowable stress 744 N/mm^2

3.5 Girder Twisting Moment:

Twisting moment is obtaining due to torsion.

As per IRC 112:2011 the torsional resistance or stiffness or stiffness of members has not been taken into account in the analysis of the structure, no specific calculation for resisting torsion will be necessary. In such cases adequate control of any torsional cracking should be achieved by providing nominal reinforcement to resist torsion.

IRC : 112-2011
cl. 7.4.2 Page. 55

Figure – 6 indicate that span vs twisting moment maximum positive twisting moment occurring at the mid of side span 1.69E+05 kN.m and maximum negative twisting moment occurring at left pylon is 4.33E+05 kN.m

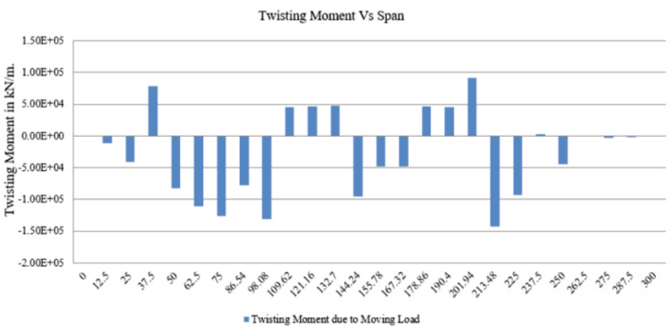

Figure 6: Girder Twisting moment due to Moving Load

3.6 Girder Bending Moment:

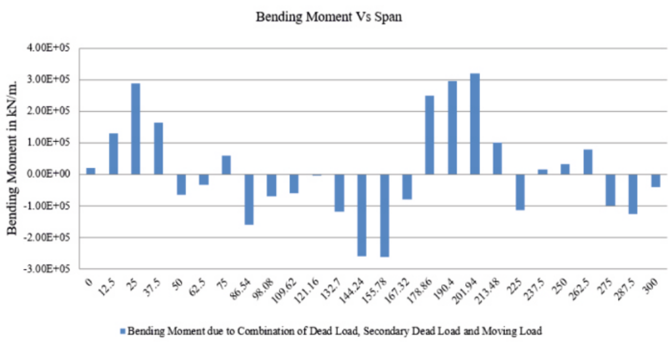

Figure 6: Girder Twisting moment due to Moving Load

3.6 Girder Bending Moment:

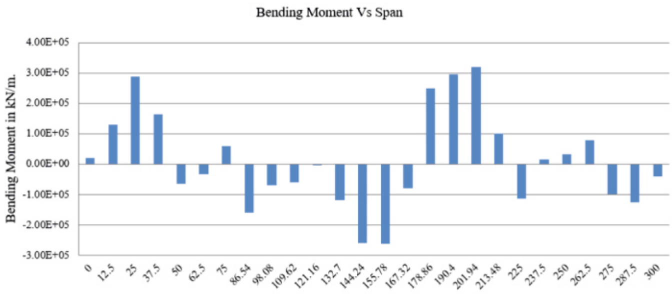

Figure 7 : Girder Bending moment due to Dead load + Secondary Dead Load + Moving Load.

Figure – 7 indicate that span vs Bending moment. The maximum bending moment under combination of dead load, SIDL and moving load occurs at main span near to the Right pylon is 3.19E+05 kN.m and maximum negative bending moment occurs at the mid of the main span is 2.64E+05 kN.m.

IV. Eigen value Analysis

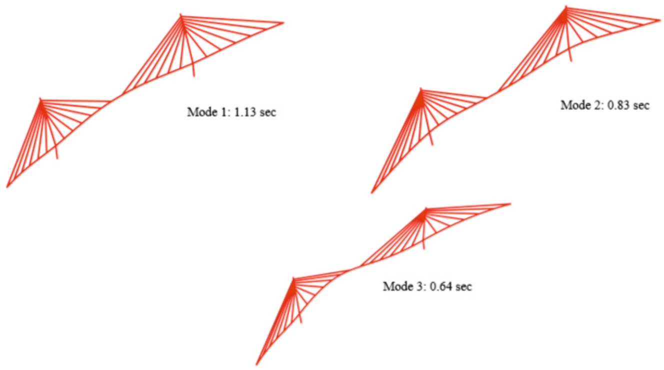

Figure 8: Eigen value Analysis

V. EFFECTS IN OPERATION STAGE

Under the combined effect of Dead Load and Secondary Dead Load maximum girder axial force at nearer to pylon is 3.00E+05 kN and the maximum axial stress is also Combination of Dead Load, Secondary Dead Load and Moving Load at the nearer pylon is 3.26E+00 N/mm2. The maximum bending moment under combination of dead load, Secondary Dead Load and moving load occurs at main span near to the Right pylon is 3.19E+05 kN.m . The maximum twisitng moment under Live Load occurs at the main span near to Right pylon is 9.14E+04 kN.m The Girder displacement under Dead Load is 0.27m is in control as per criteria of AASTHO-LRFD specifications in longitudinal direction (Criteria L/500 = 0.3m). and due to Moving Load girder displacement is 0.01364 m in traverse direction (Criteria L/1000 = 0.15m).

Under the combined effect of Dead Load, Secondary Dead Load and Moving Load the Maximum compressive stress of pylon is 11.67 Mpa.

Under the combined effect of Dead load, Secondary Dead Load and Moving Load the maximum stress of cable is 667 Mpa, smaller than the allowable stress of cable 744 Mpa.

VI. CONCLUSION

The Present research work emphasis on structural calculation based on fundamental structural engineering concept associated with IRC based aspects.

The Single tower can be effectively proposed for curve decked. Cable Stayed System performance based design (PBD) has been effectively used to check all the necessary calculations.

The Calculated parameters i.e, moments, forces and stresses are satisfying the necessary limiting values.

The Curved deck concept itself proved to be an additional milestone in cable stayed theory, which is proved to be elegant and appropriate for the coming generations.

Future Work :

Further research is needed in the following aspect of curved cable stayed bridge.

1. Behavior of pylon.
2. Performance under wind
3. Seismic loading

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